DOCUMENT RESUME

ED 298 583 CS 506 355

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TITLE Women and Communication in Mathematics: One Woman's Viewpoint.
PUB DATE Jun 88
NOTE 16p.; Paper presented at the Annual Meeting of the National Women's Studies Association (10th, Minneapolis, MN, June 22-26, 1988).
PUB TYPE Speeches/Conference Papers (150) -- Viewpoints (120)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Communication (Thought Transfer); *Females; Higher Education; Language Role; *Mathematical Vocabulary; *Mathematics Instruction; Mathematics Teachers; *Sex Fairness; Teaching Methods
IDENTIFIERS Communication Behavior; Communication Strategies

ABSTRACT

A lot of excellent work has been going on in various college departments in the area of changing the curriculum to be more friendly to women. However, mathematics is frustratingly resilient to these alterations in curriculum. Moreover, many of the proposed changes are not necessarily central to the heart of the problem. The problem of why women fail in mathematics is tied up with the issue of what happens in the classroom. What is problematic is the way in which mathematics tends to be discussed in a mode of power, of intimidation and content, or "advocacy," a mode that women have traditionally felt uncomfortable with and in which they have not been accepted, particularly when dealing with competitors and adversaries, male or female. One suggestion is to address the audience as inquirers, where the interactive mode of response explanations addresses and encourages curiosity. The response mode enables the listener to ask questions, seek answers, and generally become active in a collaborative process, a much more constructive struggle than the traditional confrontations which the advocacy mode creates. The response mode would also demand more attention by the teacher and give less security, but it would do so without intimidation. Perhaps the most productive approach would be to institute workshops where teachers could learn to be more responsive to the needs of women and men alike. (MS)

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WOMEN AND COMMUNICATION IN MATHEMATICS:

ONE WOMAN'S VIEWPOINT

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A lot of excellent work has been going on in various departments at colleges in the area of changing the curriculum to be more friendly to women. For example, in Biology, molecular cell biology has been found to have gender-limited substructures. Unfortunately, mathematics is frustratingly resilient to these alterations in curriculum, like a virus to antibiotics, one might say. By its very use of axioms and definitions and formal logic, it is so self-contained and self-generating that we will probably never see the course, "Calculus for Women."

Moreover, I feel that many of the changes that I have heard proposed are not necessarily central to the heart of the problem. Texts now include problems such as, "the farmer has 10 acres, she..", the "parachutist, she", the "sergeant, she". These changes are worthwhile, no doubt, but still feel somewhat like gratutities. Suggestions have been made to improve texts and courses by including more problems from the social sciences and areas which are supposed to have greater appeal to women. Again, while there may be desireable benefits in such changes, we would see less of the physics and engineering applications, a result not likely to please advocates for women in these areas.

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If we are going to look at why women fail in mathematics, I am afraid we are going to have to tackle seriously the troublesome issue of what happens in the classroom. Present drop-offs in college enrollments for women in mathematics are indicating the need for this. While national percentages of women obtaining Ph. D.'s are on the rise, the percentages are only very near to what they were prior to World War II (there had been a decline in numbers of women scientists in the 50's) and last year, the figures indicate that approximately 70 citizen women obtained Ph.D.'s nationwide, an unhealthy average of one and one-half women per state, hardly enough to fuel our colleges. (Actually, the most serious attrition reported was among white males. What I say here may have as much bearing on the feelings of sensitive male students as on women.)

Mathematics is a field of extraordinary power to shape our world, spawning as it does areas of statistics, decision theory, operations research, control theory, and applied mathematics, areas which may be considered traditionally within the male domain of values. But I am inclined to say that historically or in the present, there is no reason to assume that women are not interested in power values. As I view the situation, the problem for mathematics is one which involves habits and assumptions of presentation that seem to nag the mathematician, rather than one which is intrinsic to mathematics itself. What I find problematic is less that mathematics effects power, but more the way in which it tends to be discussed in a mode of power, of intimidation and contest, or "advocacy", a mode that women have traditionally felt uncomfortable in and have been unaccepted in, particularly when dealing with competitors and adversaries, male or female.

To understand some of the sense of self-importance that affects many of us mathematicians, we must understand that mathematicians may not only derive a sense of grandeur from an ability to impact on the world, but also from the fact that mathematics is the ultimate in abstracttion, and therefore, closer to "godliness". We mathematicians are spoon-fed on stories of the greatness and magic of mathematics and historically at least, perhaps we came honestly by our pride.

Pythagoras considered himself no less than a descendant of gods. Other Greeks used mathematics to discover the distance to the sun, its size, the size of the earth. Archimedes, who was a one-man Industrial Revolution, said, "Give me a place to stand and I will move the earth." He almost did, using pulleys to draw a loaded vessel from the water. (He presented a different side of godliness, you may remember, when he dashed naked in the street from his bath, yelling, "Eureka"!) Oriental mathematical history has its share of ego. A Chinese mathematics teacher noted by the change of the course of a river that his pupil would be arriving. (Although I cross the Mississippi on my way to work, this observation is one I have never made myself, something which may explain my class attendance on Fridays.) From the 1600's the history of mathematics is abrim with examples of the glory and conceit of mathematicians. Pascal and Euler did Pythagoras one better, deriving mathematically the existence of God. Leibniz, the inventor of calculus, tangled with mysticism connected with the numbers zero and one; he was a binary prophet apparently! Associations of mathematics with magic, religion, or simply metaphorical paradise continue even into more modern times. I have read that some people are presently using numerology to prove Gorbachev is the Anti-Christ.

On a smaller scale, many professors feel that commitment to the subject is no less than commitment of one's soul and expect it.

Howard Eves in his book, "In Mathematical Circles", says this about mathematicians:

> "Inherent in the study of mathematics there is an element which makes for conceit. Do not misunderstand me, I do not mean that all mathematicians are conceited. I mean that the study of mathematics, especially in the higher echelons--stressing as it must a genius for analysis and abstraction, intellectual self-sufficiency, the possibility of perfect achievement, and an almost Jehova-like power to create concepts and systems--together, perhaps, with the extraordinary power that the subject seems to have in shaping our technological civiliazation--somehow tends to encourage the element of latent unconscious self-conceit we are all born with."

I do not want to leave women out of this brief discussion of mathematicians, but I am forced to tell the joke that went around in graduate school. There were two famous women in mathematical history: one, the mistress of Weierstrass, ("she wasn't a mathematician") , and the other--Emmy Noether, who wore trousers ("and she wasn't a woman.") Today a very sincere, dedicated effort is being made by many conscientious individuals, journals, and organizations to promote women in mathematics. Unfortunately, once again for women, this effort comes at a time when mathematicians are losing their individual prominence and work is done more through collaboration, and often with machines.

Collaboration often screens out women. And much of today's research is at a point where it is necessary, as contributions can be only small pieces of complex puzzles. Science Magazine reports that mathematicians are by far the least cited scientists, and questions if mathematicians are even able to read other mathematicians. Philosophical questions by Russell and Godel now challenge the absolute validity of mathematics, and computer scientists are now achieving in microseconds what mathematicians once spent years doing, and make more money at it. On a more everyday level, mathematicians--and this includes teachers--may be frustrated at not being understood, defensive and under pressure to be brilliant themselves, and maybe--even argumentative and contesting.

Even the traditional, presumably non-emotional mode of mathematics can resemble a put-down contest mode. I would like to demonstrate by means of some phrases captured at random from textbooks, truly a vocabulary of mathematical punctuation.

We claim

The proof is trivial

The assertion follows obviously

We see at once

It follows immediately

The reader is expected to know

The theorem is now evident that

It is obvious

It is clearly impossible

It would be ridiculous

Simple but important

Is simply the result that

It is commmonly know

This well-known result

Provided, of course...

One Russian text takes the cake:
"Soviet Mathematicians have continued the great tradition of their predcessors and have created powerful new methods to obtain first class results."

In the problem sets, we see injunctions to "prove, find, show, demonstrate, compute, identify, explain, perform, estimate, evaluate, write out, determine, express, respresent, derive, give, sketch, formulate, construct, state, and answer." These commands are a far cry from my first grader's math books, which ask "Can you help the squirrel find the nuts?"

We mathematicians may be the least likely to feel anything is potentially threatening in this style: we are raised in it. In Sheila Tobias' words, we are the "insiders", and have come to view the language as a harmless battery of road signs indicating the difficulties ahead and helping the reader maintain the flow. Some mathematical writing brings to mind the distinction philosophers make between "discovery" and "justification". The story used by philosophers to illustrate the point is that of the chemist Kekule who materialized the breakthrough conjecture that the benzene molecule was a circular chain. He had a dream of a snake swallowing its tail. This was the "discovery", but "justification" would be required before a jury of chemists would accept the concept. Many math books are written as "justifications." In them, the intuition and the efforts of years of wrestling with complex issues are compressed into a few short lines of "elegant" mumbo-jumbo. Perhaps "elegance" is not what the bewildered student wants. Fortunately, modern journals and texts, depending on a pleased readership, are encouraging a new way of writing mathematics, and we are beginning to see a gentler style, a style which fixes the reader firmly in mind, one which is responsive to the reader.

> What is perhaps remarkable about what we have observed..
>
> Before we describe the algorithm we need to consider how to..
>
> If it were necessary to generate... then this approach would be hopeless
>
> The problem presents itself that we do not know.

I am not asking for the Miss Manner's approach: "The gentle reader might enjoy proving for him or herself..". I am saying, however, that the mode in which mathematics is usually written and spoken is one of advocacy, of claims and assertions, one which generally ignores its audience. It is a language which I feel is more easily adopted by men than women, if we can believe what we are told about women using fewer declarative sentences in conversation. And it is a language, which particularly, when spoken, is frequently abused with impatience, frustration, and defensiveness. Mathematical "arguments" in the rhetorical sense of the word, move easily into "argumentative" encounters. Mathematical discussions are frequently seen by one participant as ambush, and encounters like these frighten men as well as women. I find myslef saying "clearly" when I think that I mean: "Hang on, you won't find this hard when you think about it later, but please allow me to go on now." But is it heard that way? Or am I saying rather, "Don't bother me with this now: I'll lose my train of thought". Obviously, if it were so very clear, I wouldn't need to say "clearly". And did you notice the "obviously"?

In the mathematics classroom the mode is not generally interactive, and competition runs high. Besides feeling pressured to be brilliant and fast, students report that they feel inhibited by the sense of being either right or wrong. Teachers feel pressured as well, by schedules, and the need to have students pass into the next course well prepared, and we find ourselves making these kinds of remarks:

I just showed that.

You're supposed to know that, you should remember...

If you don't know that you should Review Your Algebra!

You should be able to prove this for yourself.

(Actually, I read this paper to my class, and for the rest of the term they never let me forget when I uttered one of these phrases. This illustrates two points. That I myself as a teacher so easily slip into this mode, and that students are really that sensitive to this type of language.)

As a student, I used to enjoy the (students') joke that "trivial" means the student can do it, whereas, "obvious" means even the professor can. There is another classic joke about the professor who states that a result is obvious, pauses, steps back and asks, "Is it obvious?" and comes back the next day to announce, "I thought about it last night, and it is obvious."

So, power-based as mathematics may be, most women and men would feel less alienated and even threatened if that sense of power did not loom so large in the communication transactions of the field. I have been sent a brochure by a womens' career seminars group (as most of us women teachers probably have) that advertises classes for women. Within one day in this seminar, we can overcome the 4 unconscious fears that hold women back, build our presence through our walk, expressions and gestures, make "power impresions"--the secret to instant rapport, avoid the 5 power-robbing appearance mistakes even sophisticated women make, create the power-look, eliminate the 5 female mannerisms that say you are a lightweight, and so on. Such strategies won't

make much headway in an effort to transform the personalities of half the people in the world, but I feel that they are useful as ways of thinking about classrooms and how we act as teachers there to accommodate women.

Should you want reasons why women fail in mathematics, the book, Women and Mathematics: Research Perspectives for Change offers hundreds! The book is evaluative, and doe not in any way promote all the research it catalogues, but it is interesting to see a brief list of some "yingle-yangle" areas of research, so called because they are formulated on Yin-Yang differences between males and females.

Brain hemisphere differences

Hormonal Effects in Cognition

Females better at simpler, males better at complex tasks

Adrenergic and Cholinergic antagonism

The Gout Hypothesis--to the casual eye this argument goes as follows: People with gout are bright. Men have gout. Women generally don't. Women aren't as bright as men.

Estrogens!

What gives one pause here is that the book is titled, Perspectives for "Change".

To comment briefly on another observation offered, that male variability on tests measuring mathematics achievement is greater than that for females: if true, this greater variability means a greater proportion of women than men fall into the middle range, and a greater proportion of men than women at the

higher (as well as lower range). This then suggests that higher achieving women will find greater competition with men for grades and jobs than middle-achieving women.

But what the book does discuss at length is that womens' performance in mathematics is seriously hindered by "math anxiety". This idea is being studied today with great care and concern.

In discussing mathematics, attempting as we are to enlighten and convince, we are using language, and as such we need to separate the ways in which we use it from what we are presenting, that is, the mathematical facts. We might introduce the label "advocacy" for traditional modes of exposition, and dealing out information, and the term "response" for explanation, and collaboration. For example, declaring, reminding, arguing, claiming, asserting belong to the "advocacy" mode. Whereas, explaining, describing, narrating, demonstrating, clarifying are techniques of the response mode. In the interactive mode of response explanations are given which address the audience as inquirers; they address and encourage your curiosity. In advocacy, I tell you what I want you to know, and I justify. In response I explain what you want to know and you are free to discover. The advocacy mode can create an environment of fear and often, an advanced case of "monkey-see, monkey-do". On the other hand, the response mode builds the power in the listener to ask questions, seek answers, and generally become active in a collaborative process. I am not saying that learning should not be a struggle; however, the struggle created by the response mode is constructive rather than

confrontative. If more mathematical transactions were in this mode, perhaps women would not have to be trained in workshops to be more aggressively competitive or assertive to do mathematics.

On the other hand, the response mode demands more attention of the teacher, and frequently, a much greater outlay of energy with much less security. Advocacy gives us security and speed, but it does so by intimidation, and risks becoming a possession, so that even when we try to avoid it, we drift nevertheless into it with interactions that may be destructive.

Many of us are weary of the words "mathematics anxiety" because they can imply that the woman has the burden of conquering an unnatural phobia to join the system, and the system is fair. Sometimes a more appropriate term might be "authority anxiety". But I do not want to place the entire burden of the process on the teacher, and I will now shift the responsibility back to the student, for there is, fortunately a strategy by which it becomes possible for the student to break the advocacy situation and gain control. It has been said, by Eves, that "The most fruitful utterance in the history of science is...why?" I am afraid to disappoint you with this conclusion but it's worth as a strategy, which was given to me by a friendly professor in graduate school, has been well-proven by me, time after time. It works this way: in an intimidating collaborative scene with a fellow (male) colleague, he might say that a result follows automatically from Urysohn's Lemma. This is not my field, and I don't have that result on the tips of my fingers. I can remain silent and submissive, and miss out on what ensues, or I can ask: "Remind me of the statement of that Lemma, please." Now my colleague has the responsibility of recalling its conditions and conclusions. I may then ask,

quite honestly (because the point of this transaction is not for it to become a game), "But I don't see how it applies." Or perhaps, "why should that result be true?" At any rate, that simple question, "Why? I don't understand" has the power to transform a confrontation into a dialogue, to subvert the advocate and disarm him or her. The student is now requiring the teacher to be an explainer, a cooperative one. "Why are we studying series?", "Why doesn't this series converge while this one does?", or simply, "Why is that?" are questions most of us teachers would be only too happy to attempt to answer. Incredibly, this is the one question students feel by and large they are not free to ask. Perhaps we teachers are forced by training and syllabi to see such questions as obstructive of our lecture plans. If we could build into our teaching the effort to encourage more of our students to ask "why" and if we gave ourselves the room to listen more to our students we could be contributing in the effort to make a math class a more secure place for women, and everyone else.

How can we then change the mathematics classroom to be more inviting to women and men alike? In a practical vein, questions must be treated protectively in the classroom. Students want a grading system which appears to them less of an immutable judgment. They want labs to accompany their classes, in which they will feel free to ask that stigmatized question, and they need opportunities in which to work together, inside or outside of the classroom. Writing assignments are wonderful in breaking down the teacher-student barrier and training students in the art of framing questions. My feeling is that rather than provide workshops for students to learn to be more assertive, a more productive approach might be workshops for us teachers to learn to be more responsive.

There are positive signs. Education enrollments are up, and women particularly seem drawn to mathematics education. While this is not always viewed as encouraging by research-oriented departments, perhaps with more women teachers, we will be able to see the future change. And The American Mathematical Monthly, March 1987, has noted that successful women mathematicians seem to emerge from schools in which there is emphasis on excellent teaching. I am looking forward to the day when women are able to initiate discussion with their male counterparts in which mutual respect is possible, and honest lack of understanding does not mean to lose a battle.

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